BENTHIC MACROINVERTEBRATES INHABITING THE SWASH ZONE OF PANAMA CITY BEACH, FLORIDA

Little attention has been paid to the benthic macroinvertebrates of the swash zone fronting the Gulf of Mexico on Panama City Beach, FL. Studies on the invertebrate fauna offshore of the swash zone have been studied by Hulings (1961), who listed 53 species of barnacles and decapod crustaceans collected on one transect perpendicular to the beach, and by Salsman and Tolbert (1965), who made observations on the populations of the sand dollar, *Mellita quinquiesperforata.*

This study was initiated in August 1974 and continued through July 1975, in order to deliniate the distribution and abundance of the benthic macroinvertebrates inhabiting the swash zone (defined as the beach face, or the sloping surface of the beach that is covered by the run-up of water brought by waves, Russell, 1969) of Panama City Beach, FL, in order to provide a basis for determining changes in the populations caused by natural or man-made means.

Area Description

The study area, a 34.3 km long beach, is located on the northeastern shore of the Gulf of Mexico in Bay County, FL (Fig. 1). Most of the area shoreward of the beach in the survey area has undergone development for houses and motels, but the natural beach with sand dunes still exists at St. Andrews State Park near West Pass. The beach has a relatively straight shoreline and an average width of about 26 m. A dune backs the beach at elevations of 3.0-4.6 m above mean sea level (Wilson, 1975). Two sand bars occur offshore and parallel to the beach, one about 15 to 61 m from shore and a second about 244 m offshore.

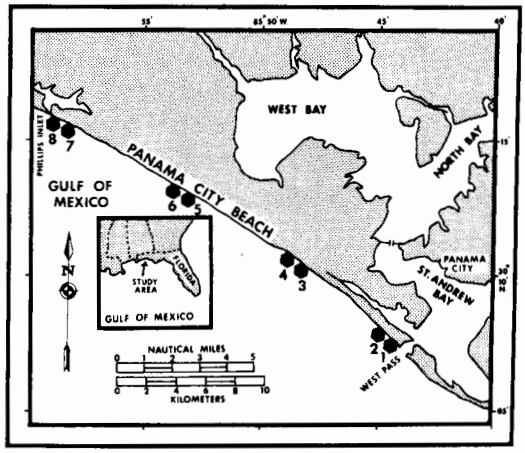

Figure 1. Station locations in the Gulf of Mexico between West Pass and Phillips Inlet.

Eight stations were established in the swash zone of this beach between West Pass and Phillips Inlet, FL (Fig. 1).

Methods

Benthic samples were collected monthly with a stainless steel plug sampler (Fig. 2). The sampler covers an area 1/64 m^2 and penetrates to a depth of 23 cm. At each station, four plug samples were taken. Samples were extruded, and then sieved in a stainless steel sieve (Fig. 2) with a mesh of 0.701 mm^2. The remnant portion was stained with Rose Bengal and preserved in 10% Formalin-seawater.

In the laboratory, the samples were rinsed in fresh water. The benthos were identified, enumerated, and placed in 70% isopropyl alcohol. The Shannon Index of general diversity ($\overline{H}$) where $\overline{H} = -\Sigma \left(\frac{n_i}{N}\right) \log_e \left(\frac{n_i}{N}\right)$ with n_i the number of individuals of a given species and N the total number of individuals (Odum, 1971) was calculated by month and by stations.

Monthly water samples were collected

only at Stations 2, 4, 6, and 8. Water temperatures were measured with a mercury thermometer. Salinities were determined with a Goldberg refractometer.

Adequacy of Sampling

To determine the number of plug samples necessary to obtain an adequate representation of the benthic species within the sampling area, twelve consecutive plug samples were collected at one site and 16 consecutive plug samples were collected at each of two other sites. The accumulative numbers of species and of individuals were plotted against the numbers of samples. The percentage of the total number of species occurring in the first four samples collected at each of the three sites was 100%, while the percentage of individuals ranged from 15 to 28%. The total number of species in the first four samples at the three sites ranged from 3 to 6 and the number of individuals ranged from 26 to 363.

In order to determine if 23 cm was an adequate sampling depth, a comparison was made between the catch in the plug sampler and the catch in a core sampler. The depth of penetration of the core sampler (6.35 cm in diameter) was 46 cm, twice that of the plug sampler. The surface area sampled with the core sampler was one-fifth that of the plug sampler. Forty core samples were taken in the swash zone, and each extracted core was divided into two 23-cm lengths. The 40 cores produced a total of 38 benthic invertebrate individuals representing seven species. Only one of the 38 individuals was found in the bottom half of the core sample.

Thus, we concluded that four plug samples taken to a depth of 23 cm would adequately sample the benthic invertebrates of the swash zone.

Hydrology

Surface water temperatures ranged 12.4 to 30.0°C and averaged 22.2°C

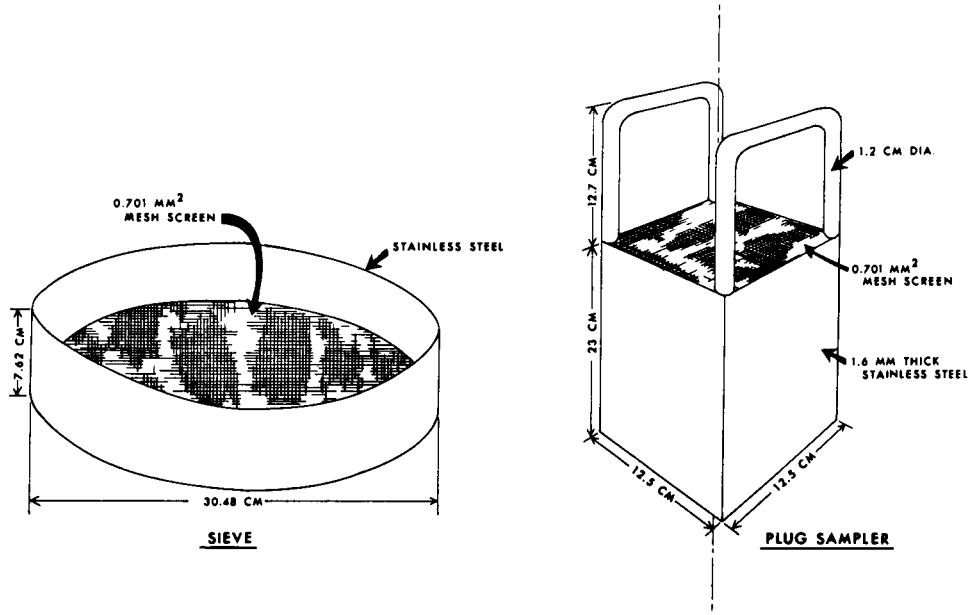

Figure 2. Quantitative plug sampler and sieve.

over the 12 months. The coldest water temperatures occurred in December 1974 and March 1975, and the warmest in August 1974 and June 1975.

Salinities ranged from 26.6 to 35.3°/∞ and averaged 31.8°/∞ over the 12 months. The lowest average salinity occurred in February, May, and June 1975, while the highest salinities were in December 1974, and January and March 1975.

Benthic Invertebrates

In 12 months of sampling at eight stations in the swash zone of Panama City Beach, FL, 9,970 individuals, represented by 19 species and 10 major taxa (Table 1) were collected.

Numbers of species were highest in the spring and summer and lowest in the fall and winter (Table 1). Of the 9,970 individuals taken during sampling, almost 1/3 occurred in July 1975 and 1/5 in May 1975. The lowest number appeared in November 1974 (Table 1).

The number of individuals per square meter ranged from 82 in November 1974 to 6,168 in June 1975 (Table 1). The monthly average for the 12-month sampling period was 1,662 individuals. The number of individuals between stations ranged from 711 at Station 8 to 2,540 at Station 2 (Table 2).

The diversity index of the benthic invertebrates inhabiting the swash zone was low, indicating a stressed or physically controlled environment and possibly patchiness of the animals. The index ranged from 0.443 in February 1975 to 1.173 in July 1975 (Table 1), and averaged 0.788 for the 12-month sampling period. By stations, the lowest index (0.796) occurred at Station 7; the highest (1.283) at Station 8. Station 8 produced the highest number of species and lowest number of individuals (Table 2).

Four species were dominant in the swash zone. These four *(Donax texasianus, Scolelepis squamata, Haustorius* sp., and *Emerita talpoida)* comprised over 99.3% of the total individuals.

The most abundant species was *D. texasianus.* It comprised 44% of all

Table 1. Numbers of benthic invertebrates collected monthly in the swash zone of Panama City Beach, Florida, from August 1974 through July 1975.

	1974					1975								
Species	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Total	Percent
NEMERTINEA														
Unidentified sp.	1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	1	0.01
NEMATODA														
Unidentified sp.	-----	-----	-----	-----	-----	-----	-----	-----	1	2	-----	-----	3	0.03
POLYCHAETA														
Paraonis fulgens	-----	-----	1	1	11	-----	-----	-----	-----	-----	-----	-----	13	0.13
Scolelepis squamata	45	3	-----	1	-----	-----	1	42	3	848	2,525	354	3,822	38.34
GASTROPODA														
Hastula salleana	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	1	-----	1	0.01
PELECYPODA														
Anadara floridana	-----	-----	-----	-----	-----	-----	-----	1	-----	-----	-----	-----	1	0.01
Cuna dalli	-----	-----	-----	-----	-----	-----	-----	-----	-----	1	1	-----	2	0.02
Donax texasianus	17	7	237	22	421	199	1,023	878	58	1,025	450	61	4,398	44.11
Unidentified venerid	-----	-----	-----	-----	-----	-----	-----	1	-----	-----	-----	-----	1	0.01
CUMACEA														
Spilocuma salomani	-----	-----	-----	-----	-----	-----	-----	1	1	-----	1	-----	3	0.03
ISOPODA														
Ancinus depressus	-----	-----	1	-----	-----	-----	-----	-----	-----	-----	-----	-----	1	0.01
Scyphacella arenicola	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	29	29	0.29
AMPHIPODA														
Acanthohaustorius sp.	-----	-----	-----	-----	-----	-----	-----	-----	1	-----	-----	-----	1	0.01
Haustorius sp.	4	27	-----	1	24	69	66	67	364	166	35	64	887	8.90
Pseudohaustorius sp.	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	1	1	0.01
Synchelidium sp.	-----	1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	1	0.01
CARIDEA														
Processa hemphilli	-----	-----	-----	-----	-----	-----	-----	-----	1	-----	-----	-----	1	0.01
ANOMURA														
Emerita talpoida	161	93	100	16	69	21	67	70	39	45	68	47	796	7.98
Lepidopa benedicti	2	-----	-----	-----	-----	-----	-----	1	-----	-----	3	2	8	0.08
Total Individuals	230	131	330	41	525	289	1,157	1,061	468	2,087	3,084	558	9,970	100.00
Total Species	6	5	4	5	4	3	4	8	8	6	8	7	19	-----
Individuals per square meter	460	262	678	82	1,050	578	2,314	2,122	936	4,174	6,168	1,116	-----	-----
Diversity Index ($\bar{H}$)	0.897	0.849	0.645	0.973	0.666	0.789	0.443	0.665	0.746	1.010	0.595	1.173	-----	-----

Table 2. Numbers of benthic invertebrates collected at each station in the swash zone of Panama City Beach, Florida, from August 1974 through July 1975.

Species	Stations 1	2	3	4	5	6	7	8	Total
NEMERTINEA									
Unidentified sp.	-----	-----	-----	-----	-----	1	-----	-----	1
NEMATODA									
Unidentified sp.	2	-----	-----	-----	-----	-----	-----	1	3
POLYCHAETA									
Paraonis fulgens	2	-----	1	1	1	2	-----	6	13
Scolelepis squamata	940	1,344	610	435	160	249	50	34	3,822
GASTROPODA									
Hastula salleana	-----	-----	-----	1	-----	-----	-----	-----	1
PELECYPODA									
Anadara floridana	-----	-----	-----	-----	-----	-----	-----	1	1
Cuna dalli	-----	1	-----	-----	-----	-----	1	-----	2
Donax texasianus	158	348	714	848	620	708	706	296	4,398
Unidentified venerid	1	-----	-----	-----	-----	-----	-----	-----	1
CUMACEA									
Spilocuma salomani	1	-----	1	-----	-----	-----	1	-----	3
ISOPODA									
Ancinus depressus	-----	1	-----	-----	-----	-----	-----	-----	1
Scyphacella arenicola	1	-----	3	2	-----	3	5	15	29
AMPHIPODA									
Acanthohaustorius sp.	-----	-----	-----	-----	-----	-----	-----	1	1
Haustorius sp.	122	130	107	257	65	100	55	51	887
Pseudohaustorius sp.	-----	-----	-----	-----	-----	-----	-----	1	1
Synchelidium sp.	-----	-----	-----	-----	1	-----	-----	-----	1
CARIDEA									
Processa hemphilli	-----	-----	1	-----	-----	-----	-----	-----	1
ANOMURA									
Emerita talpoida	53	81	73	58	161	112	133	125	796
Lepidopa benedicti	3	-----	-----	-----	2	-----	1	2	8
Total Individuals	1,283	1,905	1,510	1,602	1,010	1,175	952	533	9,970
Total Species	10	6	8	7	7	7	8	11	19
Individuals per square meter	1,711	2,540	2,013	2,136	1,347	1,567	1,269	711	-----
Diversity Index ($\overline{H}$)	0.881	0.882	1.081	1.122	1.087	1.109	0.796	1.283	-----

individuals. It was present throughout the year with highest abundance during February, March, and May 1975, when over 66% of *D. texasianus* were collected (Table 1). Its abundance was lowest in August and September. The mean length of *D. texasianus* was 12.3 mm. The size range of individuals varied from 1 to 26 mm (Table 3). Small individuals (below 5 mm) were present in almost all months, indicating the occurrence of spawning and recruitment throughout the year. The highest percentage of small individuals for any particular month occurred in October 1974 (Table 3).

The second most abundant animal was the polychate, *S. squamata.* It was present at all eight stations, although the majority occurred at stations at the east end of the study area (Table 2). This polychaete was abundant only from May through July 1975, when over 97% of the individuals occurred. In the period of September 1974 through February 1975, only five individuals were captured (Table 1).

The third most abundant species was an undescribed species of amphipod of the genus *Haustorius* (E. L. Bousfield, per. comm.). It comprised almost 9% of the total individuals and was present at all eight stations (Table 2). This species was present in 11 of the 12 months. It most commonly occurred in April and May 1975 and was least abundant in August and November 1974 and was absent in October 1974 (Table 1).

Table 3. Abundance and size of *D. texasianus* collected in the swash zone of Panama City Beach Florida.

Month	Number of individuals	Mean length	Range
		mm	mm
1974			
August	17	10.1	4-20
September	7	11.1	4-20
October	237	2.2	1-10
November	22	9.7	3-18
December	367	10.5	1-22
1975			
January	156	13.1	6-24
February	324	12.3	5-23
March	544	15.0	3-23
April	58	7.9	3-25
May	500	15.2	4-26
June	405	13.4	1-24
July	60	11.9	7-23
Total	2,697	----	1-26
Average	224.8	12.3	----

The fourth most abundant species was *E. talpoida*. It comprised about 8% of all captured macroinvertebrates. Individuals were present in all 12 months with their highest abundance in August through October 1974 and lowest in November 1974 and January 1975 (Table 1). Gravid females were present from August through October 1974, in March 1975, and May through July 1975, although they were few in number. Only 14 of 796 individuals were gravid, 8 of the 14 gravid individuals occurred in July. The mean length of *E. talpoida* was relatively small (4.2 mm); specimens from 1 to 31 mm in length were taken. Small individuals (1 or 2 mm) were taken throughout the year. This may have indicated that spawning takes place throughout the year (Table 4). In the months of August 1974 through January 1975 and in April 1975, individuals had a mean length of less than 3 mm (Table 4).

Table 4. Abundance and size of *E. talpoida* collected in the swash zone of Panama City Beach Florida.

Month	Number of individuals	Mean length	Range
		mm	mm
1974			
August	164	2.2	1-28
September	93	2.9	1-31
October	97	2.9	1-31
November	16	2.8	1- 8
December	69	2.2	1- 8
1975			
January	19	2.9	2- 4
February	65	4.4	2- 8
March	66	6.5	1-29
April	38	2.5	1-10
May	44	7.3	2-31
June	65	7.5	1-22
July	47	10.6	1-25
Total	783	—	1-31
Average	65.2	4.2	—

DISCUSSION

The benthic invertebrates inhabiting the swash zone of Panama City Beach appeared to be typical of other sandy-beach fauna found elsewhere in the Gulf of Mexico or in other oceans. Perhaps because of the physical rigors of this environment, only a few species were regular inhabitants, as the occurrence of the majority of species was irregular. The dominant species inhabiting the swash zone *(D. texasianus, E. talpoida, Haustorius* sp., and *S. squamata)* were similar to fauna from other exposed sandy beaches (Pearse *et al.*, 1942; Clark, 1969; Dexter, 1969; Croker, 1970).

The number of individuals in the swash zone fluctuated from month to month and from station to station. In regards to number of species, the fluctuation was considerably less as four species constituted 99.3% of the individuals, and these four species were usually present during any time or location in the study area. This seasonal and areal variation of individuals of the abundant species has been noted by others (Pearse *et al.*, 1942; Loesch, 1957; Keith and Hulings, 1965; Barnes and Werner, 1968; Ansell and Trevallion, 1969; Clark, 1969; Cubit, 1969; Dexter, 1969; Dillary and Knapp, 1970).

The macroinvertebrates were patchy in their distribution and diversities were low indicating an oligomictic (Paul, 1975) and stressed or physically controlled environment dominated by a few species and a large number of individuals (Odum, 1971). The principal stress factor was wave energy. In habitats of this type the value of diversity indicies

is questionable due to several factors mentioned by Goodman (1975). Low diversity values have been noted by Lie and Kisker (1970), Dexter (1969), and Boesch (1972) in areas of vigorous habitats with shifting sand, while Wilhm and Dorris (1968), Hall (1972), and Boesch (1972) recorded low diversity in areas that were under stress from pollution. Other factors contributing to stressed environments and oligomixity were high salinities, extremes in temperature, hydrostatic pressure, and low oxygen concentrations (Paul, 1975).

Recruitment of young individuals to the population of *E. talpoida* occurred throughout the year, as small individuals were present in almost all months. The presence of small individuals over a long period may have been due to several factors. Efford (1967) noted that *E. talpoida* grew only in the second summer. The larval development time was 30 days (Rees, 1959); however, differences in development time due to varying water temperatures and exposure to light have been described for other species of *Emerita* (Hanson, 1969; Efford, 1970). Spawning throughout the year by *E. talpoida* was possible, as year round spawning by *E. portoriciensis* has been observed (Goodbody, 1965). In addition, there are differences in growth and longevity between sexes (Efford, 1967) that could have accounted for the presence of small individuals in the swash zone in almost all months.

Young *D. texasianus* appeared in the swash zone in almost all months indicating a recruitment of young individuals over a long period. Abundance was highest in the spring and lowest in the warm months of August and September. The abundance in spring agreed with the findings of Loesch (1957) and McLuskey *et al.*, (1975). The scarcity in the warmer months may have been due to movement to deeper waters, as Loesch (1957) mentioned that *D. tumidus* moved to deeper water during the summer. Large individuals were scarce during late summer and early fall.

Haustoriid amphipods were common in the sandy beach community, and in some areas they constitute a major portion of the benthic macrofauna (Croker, 1968, 1970; Dexter, 1967, 1969, 1971; and Keith and Hulings, 1965). The *Haustorius* sp. inhabiting Panama City Beach closely resembled *H. canadensis* (E. L. Bousfield, pers. comm.). Although this species accounted for almost 9% of the total individuals on Panama City Beach, in some beaches haustoriid amphipods make up 50-90% of the individuals (Croker, 1968, 1970; Dexter, 1969).

The polychaete *S. squamata* has been found commonly on sandy beaches (Foster, 1971), and in intertidal areas (Croker, 1970; Taylor, 1971). This species accounted for 38% of the individuals in the present study and was abundant from May through July. The seasonal abundance was different from that found by Dexter (1969) in North Carolina. She noted that *S. squamata* was abundant in winter and spring.

Restoration of this beach is planned for the future. Sand is to be pumped ashore from 7.6 m depths. The data that are provided herein will be useful in assessing the effects of beach restoration upon the benthos of the swash zone.

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LITERATURE CITED

Ansell, A. D., and A. Trevallion. 1969. Behavioural adaptions of intertidal molluscs from a tropical sandy beach. J. Exp. Mar. Biol. Ecol. 4:9-35.

Barnes, N. B., and A. M. Werner. 1968. Seasonal variation in the sand crab *Emerita analoga* (Decapoda, Hippidae) in the Santa Barbara area of California. Limnol. and Oceanogr. 13(4):465-475.

Boesch, D. F. 1972. Species diversity of marine macrobenthos in the Virginia area. Ches. Sci. 13(3):206-211.

Clark, M. B. 1969. Distribution and seasonal dynamics of animal populations in San Diego beaches. Master's thesis, San Diego State College, 177 p.

Croker, R. A. 1968. Distribution and abundance of some intertidal and beach amphipods accompanying the passage of two hurricanes. Ches. Sci. 9(3):157-162.

_____ 1970. Intertidal sand macrofauna from Long Island, New York. Ches. Sci. 11(2):134-137.

Cubit, J. 1969. Behavior and physical factors causing migration and aggregation of the sand crab *Emerita analoga* (Stimpson). Ecology 50(1): 118-123.

Dexter, D. M. 1967. Distribution and niche diversity of Haustoriid amphipods in North Carolina. Ches. Sci. 8(3):187-192.

_____. 1969. Structure of an intertidal sandy-beach community in North Carolina. Ches. Sci. 10(2): 93-98.

_____. 1971. Life history of the sandy-beach amphipod *Neohaustorius schmitzi* (Crustacea: Haustoriidae). Mar. Biol. 8(3):232-237.

Dillergy, D. G., and L. V. Knapp. 1970. Longshore movements of the sand crab, *Emerita analoga* (Decapoda, Hippidae). Crustaceana 18(3):233-240.

Efford, I. E. 1967. Neoteny in sand crabs of the genus *Emerita* (Anomura, Hippidae). Crustaceana 13(1):81-93.

_____. 1970. Recruitment to sedentary marine populations as exemplified by the sand crab, *Emerita analoga* (Decapoda, Hippidae). Crustaceana 19(3):293-308.

Foster, N. W. 1971. Spionidae (Polychaeta) of the Gulf of Mexico and Caribbean Sea. Stud. Fauna Curacao and Caribb. Island 36:1-183.

Goodbody, I. 1965. Continuous breeding in populations of two tropical crustaceans *Mysidium columbiae* (Zimmer) and *Emerita portoricensis* Schmidt. Ecology 46 (1 and 2): 195-197.

Goodman, P. 1975. The theory of diversity-stability relationships in ecology. Quart. Rev. Bio. 50(3):237-266.

Hall, J. R. 1972. Mollusks and benthic environments in two Florida west coast bays. Master's thesis, University of South Florida, 112 p.

Hanson, A. J. 1969. The larval development of the sand crab *Hippa cubensis* (De Gaussure) in the laboratory (Decapoda, Anomura). Crustaceana 16(2):143-157.

Hulings, N. C. 1961. The barnacle and decapod fauna from the nearshore area of Panama City, Florida. Quar. Journ. Fla. Acad. Sci., 24(3):215-222.

Keith, E. E., and N. C. Hulings. 1965. A quantitative study of selected nearshore infauna between Sabine Pass and Bolivar Point, Texas. Publ. Inst. Mar. Sci. Texas 10:33-40.

Lie, U., and D. S. Kisker. 1970. Species composition and structure of benthic infauna communities off the coast of Washington. J. Fish. Res. Bd. Canada 25:2273-2285.

Loesch, H. C. 1957. Studies of the eco-

logy of the two species of *Donax* on Mustang Island, Texas. Publ. Inst. Mar. Sci. Texas 4(2):201-227.

McLusky, D. W., S. A. Wair, A. Stirling, and R. Bhargava. 1975. The ecology of a central west Indian beach, with particular reference to *Donax incarnatus*. Mar. Biol. 30:267-276.

Odum, E. P. 1971. Fundamentals of Ecology, 3rd Ed., W. B. Saunders Co., Philadelphia, 574 p.

Paul, A. Z. 1975. Benthic diversity and oligomixity at the Cariaco Trench, Venezuela, a preliminary analyses. Carib. Jour. Sci. 15(102):105-108.

Pearse, A. S., H. J. Humm, and G. W. Wharton. 1942. Ecology of sand beaches at Beaufort, North Carolina. Ecol. Monogr. 12(2):136-190.

Rees, G. H. 1959. Larval development of the sand crab, *Emerita talpoida* (Say) in the laboratory. Biol. Bull. 117(2):356-370.

Russell, R. J. 1969. Glossary of terms used in fluvial, deltaic, and coastal morphology and processes. Louisiana State University Studies, Coastal Studies Series No. 23, 97 p.

Salsman, G. G., and W. H. Tolbert. 1965. Observations on the sand dollar, *Millita quinquiesperforata*. Limnol. and Oceanol. 10(1):152-155.

Taylor, J. L. 1971. Polychaetous annelids and benthic environments in Tampa Bay, Florida. Ph.D. Thesis, University of Florida, 1332 p.

Wilhm, J. L., and T. C. Dorris. 1968. Biological parameters for water quality criteria. Bio. Sci. 18:447-481.

Wilson, D. 1975. A feasibility report for beach erosion control and hurricane protection, Panama City beaches, Florida. U. S. Army Corps of Engineers, Mobile District, 16 p. + appendices.

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